

## CLAIMS

What is claimed is:

1           1.    A method of detecting a loss of integrity in  
2   a blood circuit supplying blood to a patient, comprising  
3   the steps of:

4           detecting a leak in at least two independent ways  
5   to generate at least two leak detection signals;

6           deriving at least one composite signal responsive  
7   to said two leak detection signals;

8           generating an alarm signal responsively to said  
9   at least one composite signal.

1           2.    A method as in claim 1, wherein said step of  
2   deriving includes calculating a probability of a leak  
3   responsively to said at least two detection signals.

1           3.    A method as in claim 1, wherein said step of  
2   deriving includes combining said at least two leak  
3   detection signals such that a sensitivity of detection of a  
4   leak is enhanced.

1           4.    A method as in claim 3, wherein said step of  
2   calculating includes applying said leak detection signals  
3   to a network classifier.

1           5.    A method as in claim 1, wherein said step of  
2    deriving includes applying a respective weight to said at  
3    least two leak detection signals and adding them.

1           6.    A method as in claim 1, wherein said step of  
2    detecting includes sensing a presence of fluid outside said  
3    blood circuit and detecting a presence of air inside said  
4    blood circuit.

1           7.    A leak detection device, comprising:  
2                a first detector sensing a first condition and  
3    generating a first signal responsive thereto;  
4                a second detector sensing a second condition and  
5    generating a second signal responsive thereto;  
6                a controller programmed to generate an alarm  
7    based on a probability of a leak derived, at least in part,  
8    from said first and second signals.

1           8.    A detection device as in claim 7, wherein  
2    said first and second detectors each includes at least one  
3    of an air detector and a fluid detector.

1           9.    A leak detection device, comprising:  
2                a first detector outputting a first detection  
3    signal;  
4                a second detector outputting a second detection  
5    signal;

6 a signal combiner connected to form a combination  
7 signal responsive to both said first and second detection  
8 signals to generate an alarm output for connection to an  
9 alarm device;

10 said signal combiner being such that both a  
11 sensitivity and a reliability of leak detection represented  
12 by said combination signal is greater than said first and  
13 second detection signals alone or together;

14 said first detector being adapted to detect a  
15 first condition that is correlated with a leak in a blood  
16 circuit;

17 said second detector being adapted to detect a  
18 second condition that is correlated with a leak in said  
19 blood circuit;

20 said first and second conditions being associated  
21 with different physical phenomena.

1 10. A detection device as in claim 9, wherein  
2 said combiner includes an analog summing circuit.

1 11. A detection device as in claim 9, wherein  
2 said combiner includes a programmable processor.

1 12. A detection device as in claim 9, wherein  
2 said first detector includes at least one of a detector of  
3 air in said blood circuit, a detector of fluid outside said

4 blood circuit, a detector of pressure in said blood  
5 circuit, an image classifier connected to a camera oriented  
6 to image a patient, or a device to measure a patient heart  
7 rate, blood oxygen level, body weight, or the continuity or  
8 bioimpedance of tissue of the patient.

1 13. A leak detection device for detecting a leak  
2 in an extracorporeal blood treatment machine, comprising:

3 a first detector outputting a first detection  
4 signal;

5 a second detector outputting a second detection  
6 signal;

7 a signal combiner connected to form a combination  
8 signal responsive to both said first and second detection  
9 signals to generate an alarm output for connection to an  
10 alarm device;

11 said first detector being adapted to detect a  
12 first condition that is correlated with a probability of a  
13 leak in a blood circuit;.

14 said second detector being adapted to detect a  
15 second condition that is correlated with a probability of a  
16 leak in said blood circuit.

1 14. A detection device as in claim 9, wherein  
2 said first detector includes at least one of a detector of

3 air in said blood circuit, a detector of fluid outside said  
4 blood circuit, a detector of pressure in said blood  
5 circuit, an image classifier connected to a camera oriented  
6 to image a patient, or a device to measure a patient heart  
7 rate, blood oxygen level, body weight, or the continuity or  
8 bioimpedance of tissue of the patient.

9 15. A method of detecting an alarm condition in  
10 a medical treatment machine, comprising the steps of:

11 combining detector signals from at least two  
12 indicators of an alarm condition such that a prediction of  
13 an alarm state is generated thereby and such that said  
14 prediction possesses at least one of a higher reliability  
15 and a higher sensitivity than said detectors signals  
16 uncombined;

17 generating an alarm signal responsively to said  
18 prediction.

19 16. A method as in claim 15, wherein said  
20 medical treatment machine is a blood processing machine and  
21 said alarm condition is a leak of fluid therefrom.

22 17. A method as in claim 16, wherein said alarm  
23 condition is a leakage of blood from a blood circuit of  
24 said blood processing machine.

25           18. A method as in claim 15, wherein said at  
26   least two different indicators of a status of a patient,  
27   medical treatment machine, or environment thereof.

28           19. A method as in claim 18, wherein said  
29   different indicators include at least two of respective  
30   ones of a video image of a patient, a blood oxygen level of  
31   a patient, a body weight of a patient, a bioimpedance of a  
32   patient's tissue, a body temperature of a patient, a heart  
33   rate of a patient, a blood pressure of a patient, a  
34   breathing rate of a patient, a presence of fluid, and a  
35   presence of air in a fluid circuit.

36           20. A method as in claim 15, wherein said step  
37   of combining includes deriving a probability of an alarm  
38   condition, said alarm signal indicating said probability.

39           21. A method as in claim 15, wherein said step  
40   of combining has the effect of amplifying a reliability of  
41   an estimate of said alarm condition indicated by said  
42   signal relative to any one of said detector signals alone  
43   by cumulating influence of multiple detector signals to  
44   generate a linear or non-linear combination.

45           22. A method as in claim 15, wherein said step  
46   of combining has the effect of amplifying a sensitivity of  
47   an estimate of said alarm condition indicated by said

48 signal relative to any one of said detector signals alone  
49 by cumulating influence of multiple detector signals to  
50 generate a linear or non-linear combination.

51           23. A method as in claim 22, wherein said step  
52 of combining also has the effect of amplifying a  
53 reliability of an estimate of said alarm condition  
54 indicated by said signal relative to any one of said  
55 detector signals alone by said cumulation of influence of  
56 multiple detector signals to generate a linear or non-  
57 linear combination.

58           24. A method as in claim 15, wherein said step  
59 of combining includes combining with a network classifier.

60           25. A method of detecting a leak from a medical  
61 treatment machine, comprising:

62           combining at least two respective ones of  
63 detector signals providing a video image of a patient, a  
64 blood oxygen level of a patient, a body weight of a  
65 patient, a bioimpedance of a patient's tissue, a body  
66 temperature of a patient, a heart rate of a patient, a  
67 blood pressure of a patient, a breathing rate of a patient,  
68 a presence of fluid, and a presence of air in a fluid  
69 circuit;

70           said step of combining being effective to yield a  
71 prediction of a leakage of fluid from said medical  
72 treatment machine.

73           26. A method as in claim 25, wherein said step  
74 of combining includes deriving a probability of an alarm  
75 condition, said alarm signal indicating said probability.

76           27. A method as in claim 25, wherein said step  
77 of combining has the effect of amplifying a reliability of  
78 an estimate of said alarm condition indicated by said  
79 signal relative to any one of said detector signals alone  
80 by cumulating influence of multiple detector signals to  
81 generate a linear or non-linear combination.

82           28. A method as in claim 25, wherein said step  
83 of combining has the effect of amplifying a sensitivity of  
84 an estimate of said alarm condition indicated by said  
85 signal relative to any one of said detector signals alone  
86 by cumulating influence of multiple detector signals to  
87 generate a linear or non-linear combination.

88           29. A method as in claim 25, wherein said step  
89 of combining also has the effect of amplifying a  
90 reliability of an estimate of said alarm condition  
91 indicated by said signal relative to any one of said  
92 detector signals alone by said cumulation of influence of



93 multiple detector signals to generate a linear or non-  
94 linear combination.

95 30. A method as in claim 29, wherein said step  
96 of combining includes combining with a network classifier.

97 31. A method as in claim 25, wherein said step  
98 of combining includes combining with a network classifier.

99 32. A method as in claim 25, wherein said  
100 medical treatment machine includes an extracorporeal blood  
101 circuit.

102 33. A method as in claim 25, wherein said  
103 medical treatment machine includes a fluid circuit.

104 34. A device for detecting an alarm condition in  
105 a medical treatment machine, comprising:

106 a signal filter adapted to combine detector  
107 signals from at least two indicators of an alarm condition  
108 such that a prediction of an alarm state is generated  
109 thereby and such that said prediction possesses at least  
110 one of a higher reliability and a higher sensitivity than  
111 said detectors signals uncombined;

112 said signal filter being further adapted to  
113 generate an alarm signal responsive to said prediction.

114           35. A device as in claim 34, wherein said  
115 medical treatment machine is a blood processing machine and  
116 said alarm condition is a leak of fluid therefrom.

117           36. A device as in claim 35, wherein said alarm  
118 condition is a leakage of blood from a blood circuit of  
119 said blood processing machine.

120           37. A device as in claim 34, wherein said at  
121 least two different indicators of a status of a patient,  
122 medical treatment machine, or environment thereof.

123           38. A device as in claim 37, wherein said  
124 different indicators include at least two of respective  
125 ones of a video image of a patient, a blood oxygen level of  
126 a patient, a body weight of a patient, a bioimpedance of a  
127 patient's tissue, a body temperature of a patient, a heart  
128 rate of a patient, a blood pressure of a patient, a  
129 breathing rate of a patient, a presence of fluid, and a  
130 presence of air in a fluid circuit.

131           39. A device as in claim 34, wherein said  
132 prediction includes a probability of an alarm condition,  
133 said alarm signal indicating said probability.

134           40. A device as in claim 34, wherein said signal  
135 filter combines said detector signals by cumulating

136 influences of multiple detector signals to generate a  
137 linear or non-linear combination thereof.

138 41. A device as in claim 34, wherein said signal  
139 filter includes a network classifier.

140 42. A device for detecting a leak from a medical  
141 treatment machine, comprising:

142 a signal filter connected to combine at least two  
143 respective ones of detector signals providing a video image  
144 of a patient, a blood oxygen level of a patient, a body  
145 weight of a patient, a bioimpedance of a patient's tissue,  
146 a body temperature of a patient, a heart rate of a patient,  
147 a blood pressure of a patient, a breathing rate of a  
148 patient, a presence of fluid, and a presence of air in a  
149 fluid circuit;

150 said signal filter being configured such that a  
151 prediction of a leakage of fluid from said medical  
152 treatment machine is generated by combining said at least  
153 two.

154 43. A device as in claim 42, wherein said  
155 prediction includes a probability of an alarm condition,  
156 said alarm signal indicating said probability.

157 44. A device as in claim 42, said signal filter  
158 combines said detector signals by cumulating influences of

159 multiple detector signals to generate a linear or non-  
160 linear combination thereof.

161 45. A device as in claim 44, wherein said signal  
162 filter includes a network classifier.

163 46. A device as in claim 42, wherein said signal  
164 filter includes a network classifier.

165 47. A device as in claim 42, wherein said  
166 medical treatment machine includes a fluid circuit.

167 48. A device as in claim 42, wherein said  
168 medical treatment machine includes an extracorporeal blood  
169 circuit.

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